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Now, putting the origin at the centre, we have

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1, \quad x^2 + y^2 = r'^2, \quad \frac{x^2}{a^4} + \frac{y^2}{b^4} = \frac{1}{p'^2};$$

whence

$$a^2 + b^2 - r'^2 = \frac{a^2 b^2}{p'^2},$$

$$r' = p' \frac{dr'}{dp'} = \frac{a^2 + b^2 - r'^2}{r'} = \frac{r(2a - r)}{r'}, \text{ by (6),}$$

$$\frac{r'}{r} = \frac{a}{r'}.$$

We have now

$$r\varphi \frac{d}{dr} \left[ \frac{F}{\varphi} \right] dr + r'\varphi' \frac{d}{dr'} \left[ \frac{F'}{\varphi'} \right] dr' = 0$$

$$r' = \frac{ar'}{r}, \quad \varphi = \frac{\mu}{r^2}, \quad \varphi' = \mu' r', \quad r' dr' = (r - a) dr.$$

Making the proper substitutions we obtain

$$\frac{1}{r^2(a - r)} \frac{d}{dr} (Fr^2) = \frac{a}{r'} \frac{d}{dr'} \left[ \frac{F'}{r'} \right],$$

the same as (7).

[*Joseph Bowden, Jr.*]

## EXERCISES.

348

PROVE that, if  $0 < a < \beta$ ,

$$\int_a^\beta \log \frac{\beta - x}{x - a} \frac{dx}{x} = \frac{1}{2} \left[ \log \frac{\beta}{a} \right].$$

[*Frank Morley.*]

349

INTEGRATE the differential equation

$$dy = \arcsin(x^2) dx.$$

[*Artemas Martin.*]

## 350

LET  $p_1, p_2, p_3$  be the points of contact of parallel tangents to a cardioid. Let them be in positive order. Let  $p_2 p_3 q_1, p_3 p_1 q_2, p_1 p_2 q_3$  be positive equilateral triangles. Prove that  $q_1, q_2, q_3$  lie on a line parallel to the tangents.

[*Frank Morley.*]

## 351

THE outer coatings of two condensers,  $A$  and  $B$ , are put to earth, and their inner coatings are connected together through a galvanometer, the resistance of which is  $g$ . The capacities of the condensers are  $C$  and  $c$ , respectively. Both are charged initially to the same potential difference,  $V_0$ , and then have charges of  $Q_0$  and  $q_0$ , respectively. Show that if the inner coatings of  $A$  and  $B$  are put to earth simultaneously through wires of no self-induction, but of resistance  $R$  and  $r$ , respectively, the charge on  $A$  after  $t$  seconds will be

$$Q = \frac{Q_0}{2x} \epsilon^{\frac{-t(\mu + \mu')}{2m}} \left\{ \left[ x + \mu + \mu' - \frac{2m}{CR} \right] \epsilon^{\frac{\kappa t}{2m}} + \left[ x - \mu - \mu' + \frac{2m}{CR} \right] \epsilon^{\frac{-\kappa t}{2m}} \right\},$$

where  $\lambda = rCR, \lambda' = rcR$ ,

$$\mu = cr(g + R), \quad \mu' = CR(g + r),$$

$$m = CcgRr, \text{ and } x^2 = 4\lambda\lambda' + (\mu - \mu')^2.$$

Show also that the whole quantity of electricity which passes through the galvanometer during the discharge, will be

$$M = \frac{Q_0 \{ C^2 R^2 (\mu\mu' - \lambda\lambda') + m^2 - mCR(\mu + \mu') \}}{C^2 R^2 (\mu\mu' - \lambda\lambda')} = \frac{Q_0 (CR - cr)}{C(g + r + R)}.$$

It is to be noticed that  $\mu\mu' - \lambda\lambda'$  can never be zero. If  $CR = cr, M = 0$ , as is the case in De Sauty's method of comparing the capacities of two condensers. In applying the expressions written above to numerical problems,

one sometimes needs to know that one  $\left\{ \begin{array}{l} \text{microfarad} \\ \text{ohm} \\ \text{microcoulomb} \end{array} \right\}$  is equivalent to  $\left\{ \begin{array}{l} 10^{-15} \\ 10^9 \\ 10^{-7} \end{array} \right\}$   
 absolute electromagnetic units, and to  $\left\{ \begin{array}{l} 9 \times 10^5 \\ 9^{-1} \times 10^{-11} \\ 3 \times 10^3 \end{array} \right\}$  absolute electrostatic units

of  $\left\{ \begin{array}{l} \text{capacity.} \\ \text{resistance.} \\ \text{quantity.} \end{array} \right\}$

[*B. O. Peirce.*]